

(12) UK Patent Application

(19) GB (11) 2 248 500 (13) A

(43) Date of A publication 08.04.1992

(21) Application No 9117908.5

(22) Date of filing 20.08.1991

(30) Priority data

(31) 9018215

(32) 20.08.1990

(33) GB

(71) Applicant

National Research Development Corporation

(Incorporated in the United Kingdom)

101 Newington Causeway, London, SE1 6BU,
United Kingdom

(72) Inventor

Michael Geoffrey Somekh

(74) Agent and/or Address for Service

R Cullis

National Research Development Corporation, Patent
Department, 101 Newington Causeway, London,
SE1 6BU, United Kingdom

(51) INT CL^s
G01B 11/30 9/02

(52) UK CL (Edition K)

G1A AA2 AA9 ACE AC5 AD4 AG1 AG2 AP14 AP17
AP3 AP6 AR7 AS12 AS4 AT14 AT26
U1S S1936

(56) Documents cited

GB 2193859 A EP 0167410 A2 EP 0108497 A1
L.B.M. TECHNICAL DISCLOSURE BULLETIN VOL. 29
NO. 12 MAY 1987
"OPTICAL MEASUREMENT DEVICE" PAGES 5361
TO 5363.

(58) Field of search

UK CL (Edition K) G1A
INT CL^s G01B

(54) Optical topographic measuring apparatus with a reference beam and a multi-frequency modulated probe beam

(57) Optical apparatus for measuring the topographic properties of a surface uses a beam of coherent radiation which is split by a beam splitter (2) into a reference beam and a probe beam. The probe beam is modulated by a Bragg cell (3) which is switched at two or more frequencies (ω_1, ω_2). Recombining the reference beam and the components of the probe beam after reflection produces a plurality of tone bursts which are detected and the phase differences therein correspond to variations in the surface topography.

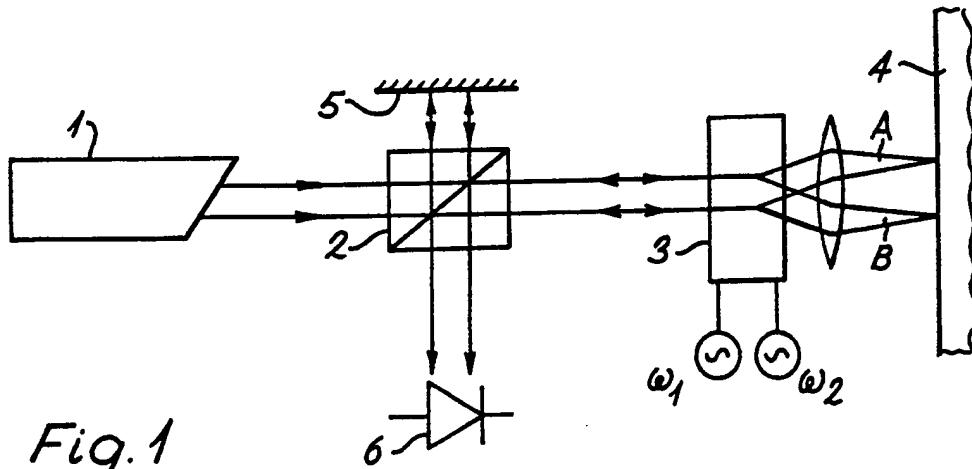
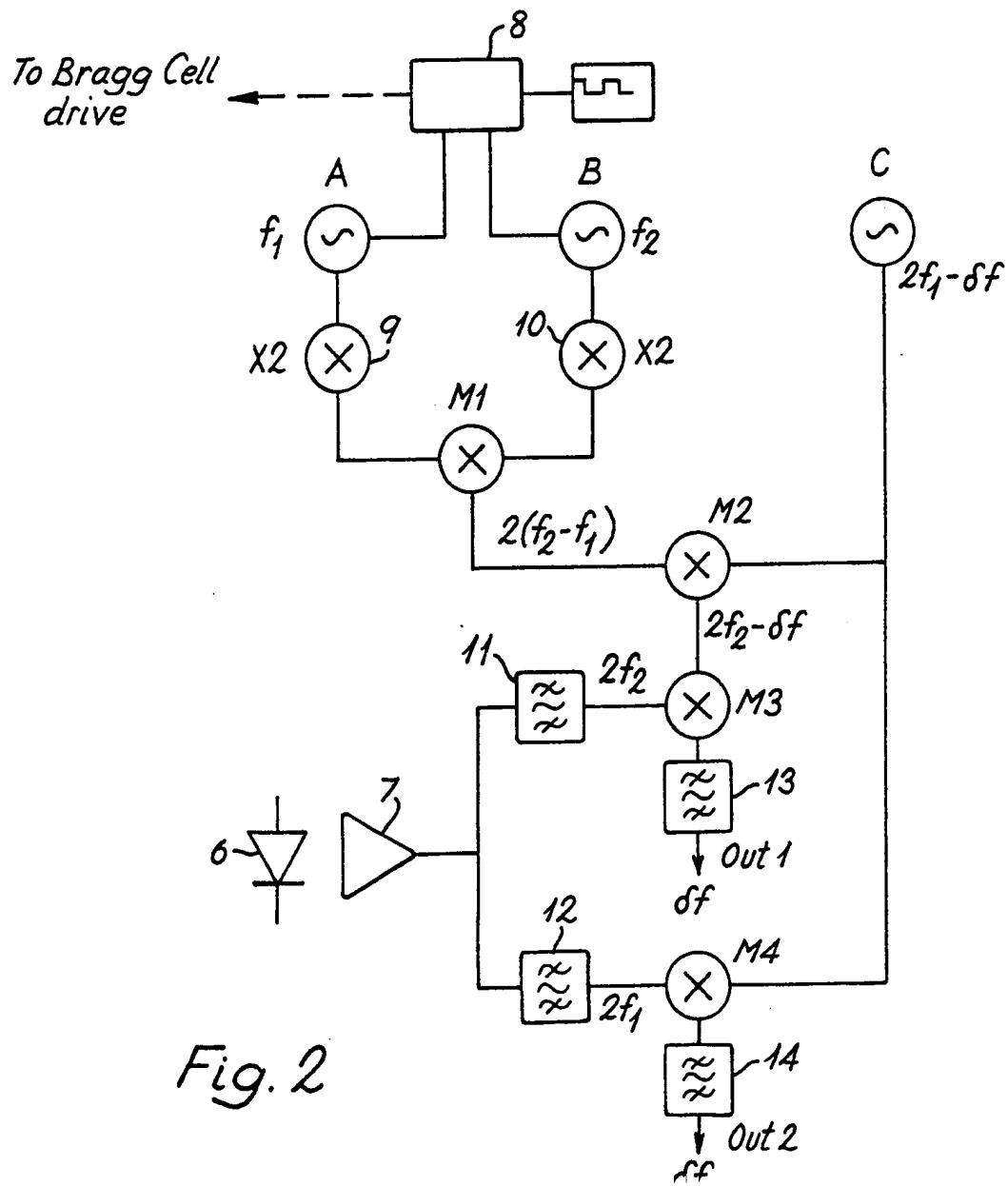
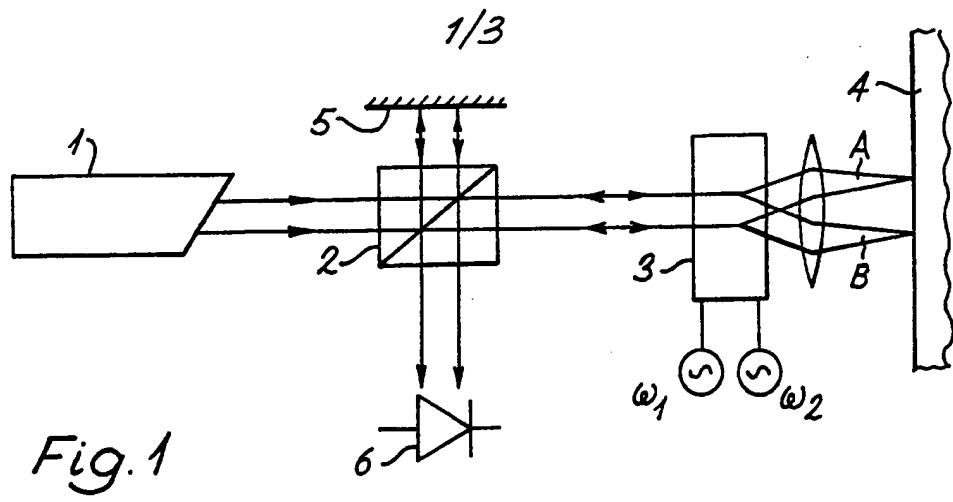


Fig. 1

GB 2 248 500 A



2/3

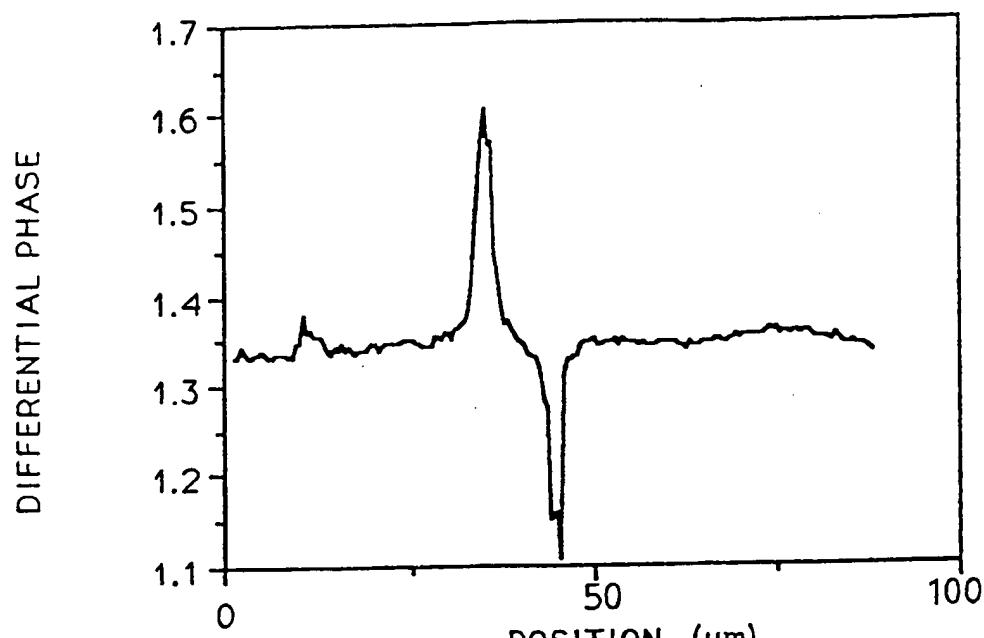


Fig. 3

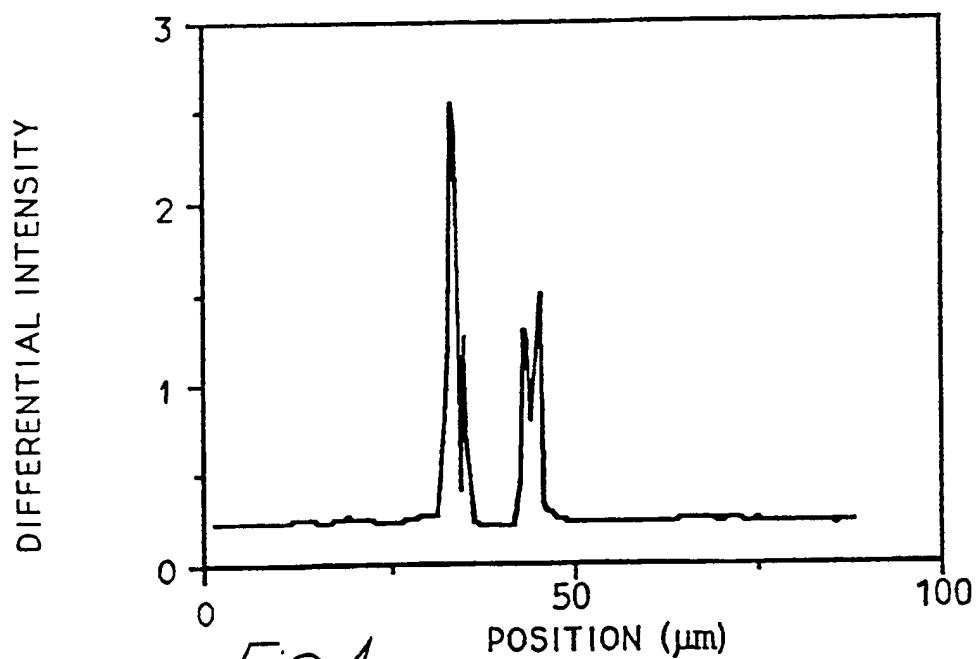


Fig. 4

3/3

DIFFERENTIAL PHASE

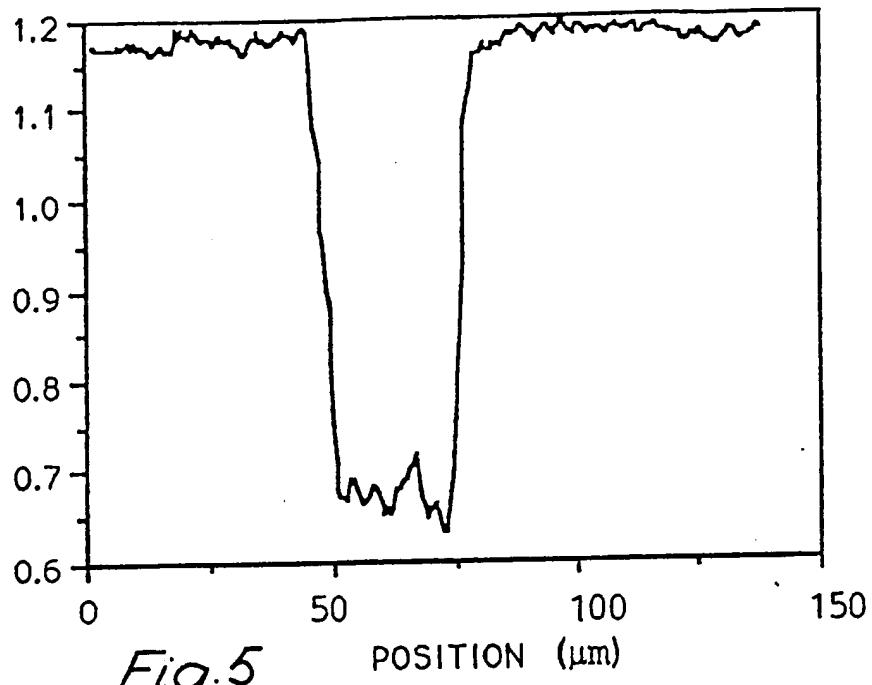


Fig. 5

DIFFERENTIAL INTENSITY

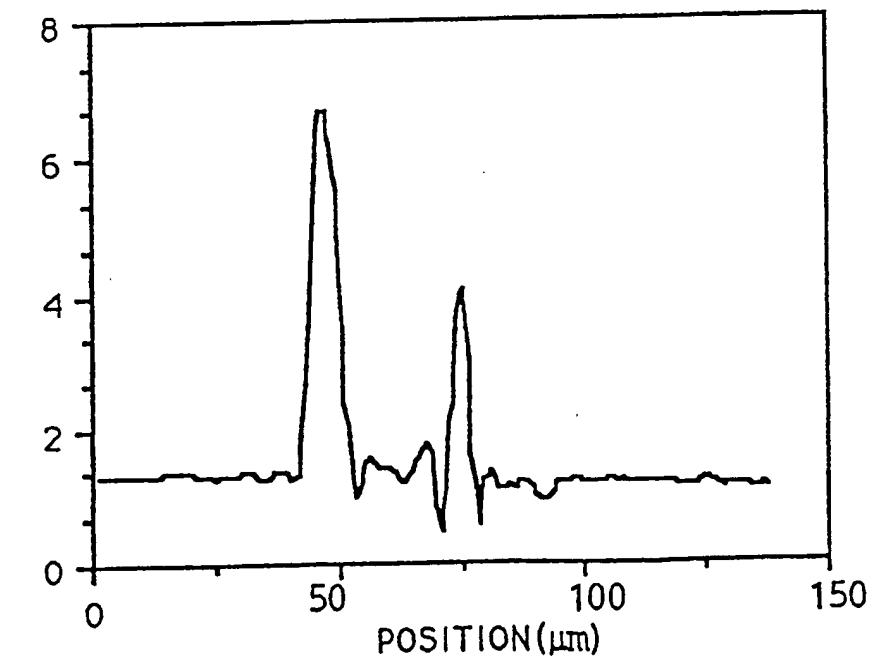


Fig. 6

- 1 -

Optical apparatus

This invention relates to optical apparatus and, in particular, to time division multiplexed amplitude and phase 5 microscopes.

In our prior British Patent Application No. 8907230.0 we describe a scanning optical microscope which simultaneously permits the measuring of the differential of the phase and amplitude of light reflected from an object.

10 We have now devised a time division multiplexed microscope which overcomes many of the disadvantages of the previous implementations of the combined differential amplitude and phase systems. Essentially it permits the achievement of optimum modulation for both the phase and intensity signals, which means 15 much superior signal to noise is possible. Optically the performance is achieved by using a common reference arm which interferes with each beam independently, the output from each of these interferometers is then compared in the electronics. The system retains advantages of common path operation reported for 20 previous implementations but allows the intensity modulation to be altered without effecting the interference efficiency in the manner noted with our previous systems.

According to the present invention there is provided optical apparatus for measuring the topographic properties of a surface 25 comprising a source of coherent radiation, means for splitting a beam of radiation from said source into a reference beam and a probe beam, means for sequentially modulating said probe beam at at least two frequencies, means for recombining said probe beam after reflection and said reference beam to create an 30 interference pattern and detector means to detect said interference pattern and to produce a plurality of tone bursts corresponding to sequential variations in said interference pattern.

The invention will now be particularly described with 35 reference to the accompanying drawings in which:

Figure 1 is a diagrammatic representation of apparatus in accordance with an embodiment of the invention;

Figure 2 is a schematic drawing of an electronic circuit for use with the apparatus of Figure 1; and

5 Figures 3-6 are graphs showing results obtained with the apparatus of Figure 1.

Referring now to the drawings, Figure 1 shows the configuration of the optical system of one embodiment of the invention. Light from a laser 1 passes through a beam splitter 10 2 to an acousto-optic Bragg cell 3 where it is deflected through an angle proportional to the frequency of the acoustic wave incident passing through the cell, ω_1 or ω_2 . The light passing through the Bragg cell is focused telecentrically on to a sample 4 after which it is reflected back through the Bragg cell where 15 it suffers a second frequency shift. A second component of the light beam from the laser 1 is reflected from a reference mirror 5 (the common reference arm) and interferes with each reflected beam in turn giving interference terms at $2\omega_1$ and $2\omega_2$ respectively which are detected by a photodiode 6. If these 20 signals are mixed electrically the relative phase between the two signals corresponds to the relative optical phase between the two beams. Since these beams are close to each other on the sample the phase difference gives the differential phase on the object surface.

25 The system interferes each beam with the common reference arm which allows each beam to be modulated separately whilst still allowing the relative phase between the two sample beams to be recovered. The two beams are modulated with antiphase square waves so that beam A is 'on' whilst beam B (shown in 30 Figure 1) is 'off', and vice versa. This is the optimum modulation scheme for differential intensity signal since it gives the best signal to noise and is much easier to implement practically. If the two beams were interfered directly this modulation would not give any interference signal since the two 35 beams would not overlap in time. The common reference beam

allows one to achieve this interference provided an appropriate electronic detection is used. This is shown in Figure 2.

The output from the photodetector 6 which is fed to a pre-amplifier 7 is two tone bursts $2f_1, 2f_2$ in antiphase. Since 5 neither overlap in time, they cannot be mixed to recover the relative phase. The tone bursts are fed by way of a single pole, double throw switch 8 and multipliers 9,10 to a mixer M1. The output at twice the difference frequency is fed to a further mixer M2. Output from the pre-amplifier 7 is fed to a pair of 10 filters 11,12 which select the second harmonics of the fundamental frequencies of the two tone bursts. The second harmonics are fed to further mixers M3,M4 and the outputs taken by way of filters 13,14. The purpose of the electronic configuration is twofold (a) to mix the signals to a common 15 frequency and (b) to pass them through a sufficiently narrow filter which, whilst not substantially reducing the data rate, converts each signal into a continuous wave signal whose phase can be compared at the two outputs shown on Figure 2.

The net result is that we have constructed two 20 interferometers operating at different times. Each operates essentially independently in the optical system. The phase of each is, however, recovered because they are interfered with the same reference beam. The electronic configuration then recovers the relative phase between the two beams in the manner described 25 above. The effects of vibrations are cancelled because each beam traverses the same path. The preliminary results illustrated in Figure 3 to 6 show respectively the differential phase and intensity over a dust spot and the differential phase and intensity as a step is scanned. These indicate that, 30 provided a stabilised laser source is used, one can achieve excellent results which are superior in terms of signal to noise to those obtained previously with the direct interference systems. The system is also much less sensitive to very fine adjustment that is required in the sinusoidally modulated scheme.

35 With the apparatus of the present invention, the

differential intensity and differential phase signal have an improved signal to noise ratio. In the case of the differential intensity signal the requirement to get a very accurate phase difference between the drives to each beam is a lot easier to achieve so that spurious signals are reduced. This is made possible by the use of two interferometers operating in parallel in a time division multiplexed manner.

Claims

1. Optical apparatus for measuring the topographic properties of a surface comprising a source of coherent radiation, means for splitting a beam of radiation from said source into a reference beam and a probe beam, means for sequentially modulating said probe beam at at least two frequencies, means for recombining said probe beam after reflection and said reference beam to create an interference pattern and detector means to detect said interference pattern and to produce a plurality of tone bursts corresponding to sequential variations in said interference pattern.
2. Optical apparatus for measuring the topographic properties of a surface as claimed in claim 1 wherein said means for modulating said probe beam comprises an acousto-optic Bragg cell adapted to deflect said probe beam through an angle dependent on an applied modulating frequency.
3. Optical apparatus for measuring the topographic properties of a surface as claimed in claim 1 or claim 2 wherein said detector means includes mixer means to mix signals corresponding to said tone bursts to a common frequency.
4. Optical apparatus for measuring the topographic properties of a surface as claimed in claim 3 further including filter means to convert respective ones of said signals to substantially continuous wave signals.
5. Optical apparatus for measuring the topographic properties of a surface as claimed in claim 4 wherein said detector means includes further mixer means and filter means to produce output signals for phase comparison.

Patents Act 1977

Examiner's report to the Comptroller under
Section 17 (The Search Report)

Application number

9117908.5

Relevant Technical fields

(i) UK CI (Edition K) G1A

5 (ii) Int CI (Edition) G01B

Search Examiner

J A WATT

Databases (see over)

(i) UK Patent Office

(ii)

Date of Search

10 DECEMBER 1991

Documents considered relevant following a search in respect of claims 1 TO 5

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	GB 2193859 A (NATIONAL RESEARCH DEVELOPMENT CORPORATION) whole document	1 to 3
A	EP 0167410 A2 (LELAND STANFORD JUNIOR UNIVERSITY) whole document	1 to 5
A	EP 0108497 A1 (NATIONAL RESEARCH DEVELOPMENT) whole document	1 to 5
A	IBM TECHNICAL DISCLOSURE BULLETIN Vol.29 No.12 May 1987 "Optical Measurement Device" pages 5361 to 5363 whole document	1 to 3

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- BLACK BORDERS**
- IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- FADED TEXT OR DRAWING**
- BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- SKEWED/SLANTED IMAGES**
- COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- GRAY SCALE DOCUMENTS**
- LINES OR MARKS ON ORIGINAL DOCUMENT**
- REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.